Attachment F – Benefit-Cost Analysis

Commonwealth of Massachusetts

Ph2AttFBCAMA.pdf

1. Process for Preparing the Benefit-Cost Analysis

This benefit-cost analysis (BCA) has been prepared for the Commonwealth of Massachusetts' proposed Trees for Resilience Program, which is described in detail in Exhibit E – Soundness of Approach. This BCA was prepared by AECOM in close coordination with the Commonwealth. The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) developed the project costs using a variety of resources, including detailed budget information from the existing statewide tree planting program called Greening the Gateway Cities Program (GGCP; http://www.mass.gov/eea/pr-2015/greening-the-gateway-cities-program-expanded.html) that involves planting trees in low income urban neighborhoods, and tree box filter unit cost information from the United States Environmental Protection Agency (USEPA) (https://www.dropbox.com/s/db16xs6p934ibac/EPA-GI%20Fall%20River%20Compiled%20Report%20DRAFT%2001-29-15.pdf?dl=0). AECOM developed the benefits of the project by conducting literature review, research, and using benefit estimating tools such as the National Tree Benefit Calculator (http://www.treebenefits.com/calculator/), which is based on the United States Department of Agriculture (USDA) Forest Service's peer-reviewed i-Tree software suite (http://www.itreetools.org/). The identified benefits and costs were quantified where possible, and those benefits and costs that are difficult to quantify or monetize were qualitatively discussed. The BCA resulted in development of a benefit-cost ratio (BCR) for the project.

2. Full Proposal Cost

Table 1 and Table 2 present the costs of the Trees for Resilience Program. The costs reported in Table 1 reflect all aspects of purchase, installation, and watering costs for the tree plantings, and the costs reported in Table 2 include all aspects of design, installation, and operations and maintenance costs for the tree box filters. A total of $2.79 million in CDBG-NDR funds is requested for public property right of way plantings and tree box filter installations; a two-year public outreach effort to identify tree planting locations in Springfield, coordinate watering agreements, and train tree planting crews; and a water quality monitoring program to assess the performance of the tree box filters in Springfield. An additional $2.78 million in other funds secured by EEA will be used for plantings on private property, for a total project cost of $5.67 million. Additional detail on project costs is included in Exhibit E – Soundness of Approach.

Table 1. Tree Planting Costs

Community	No. of Public Trees (40% of trees - HUD)	No. of Private Trees (60% of trees - EEA)	Total No. of Trees	Public Tree Planting Cost (HUD)	Private Tree Planting Cost (EEA)	Total Cost
Greenfield	386	579	965	$366,700	$332,925	$699,625
Springfield	2,834	4,251	7,085	$1,894,550*	$2,444,325	$4,338,875
TOTAL	3,220	4,830	8,050	$2,261,250	$2,777,250	$5,038,500

* Cost includes $265,000 over two years for ReGreen Springfield to conduct outreach and educational efforts that will work within Springfield neighborhoods to locate appropriate tree locations, coordinate tree watering agreements and train tree planting crews.

Table 2. Tree Box Filter Costs

Community	No. of Tree Box Filters	Cost (HUD)
Greenfield	12	$141,432
Springfield	25	$389,650*
TOTAL	37	$531,082

* Cost includes $50,000 for UMass Amherst to establish a water quality monitoring program for the tree filters and control sites within the City of Springfield.

3. Current Situation and Problem to be Solved

The tornadoes that ripped through Springfield in 2011 destroyed approximately 7,500 trees, which dramatically reduced the canopy cover in portions of the city and eliminated the environmental, social, and economic benefits these trees provided. The City of Greenfield, which is located in the Deerfield River watershed, was heavily impacted by Hurricane Irene. Primary impacts from this natural disaster were related to flooding and stormwater, but several trees were also destroyed in the city.

Hurricane Irene resulted in significant stormwater damages to both Greenfield and Springfield. As precipitation and the number of storms will increase with climate change, the stormwater benefits resulting from this proposed project will help reduce future flooding and related pollution- and erosion-related impacts and serve as a model for justification of installing more tree box filters throughout Greenfield and Springfield where urban neighborhoods drain to the Connecticut River. For example, each tree box filter will reduce annual runoff by approximately 25,000 gallons (http://cals.arizona.edu/cochise/waterwise/waterharvest.html) and each tree box filter will remove the following percentage of pollutants – TSS (82%), TPH (71%), TZn (93%) and TP (52%) (Houlem, James J., Puls, Timothy A., and Thomas P. Ballestero 2012).

The trees and tree box filters will reduce stormwater flows within the developed downtown areas. The investment in public trees and tree box filters will be returned in reduced stormwater and combined sewer overflow treatment costs (Deutsch, B., et al., 2007). In addition, planting trees will reduce impacts to housing and infrastructure due to hurricanes and tornadoes.

A co-benefit is that trees will save summer and winter energy costs, reduce the urban heat island effect which is being amplified by climate change, and reduce peak heat days and the associated health impacts for the elderly and vulnerable populations that live in these downtown neighborhoods. The number of days above 90 degrees is projected to increase significantly in future decades and will have an inordinate impact on low income residents of these downtown areas. Tree planting will also increase the resilience of the urban canopy in the two cities which are currently composed of scattered, aging trees of very few species (majority are Norway Maples which are highly vulnerable to the Asian Longhorn Beetle and other invasive species). It will increase the species and age diversity of the urban forest, making it more resilient to future pest and storm impacts, and allow the neighborhoods to retain more tree cover after significant hurricane wind events.

The entire cities of Greenfield and Springfield are considered low and moderate income (LMI) area. The vulnerable LMI populations in both cities will benefit from reduced flooding, reduced pollution in nearby waters, reduced risk of high wind, and reduced costs of cooling and heating. The model for planting trees in urban low income neighborhoods has been proven in the following cities through the state's existing GGCP program: Worcester, Chelsea, Fall River, Revere, and Chicopee.

4. Proposal Description

The Commonwealth has an existing statewide GGCP (https://www.dropbox.com/s/sm6r4bqhf7wg7yk/GGC%20REPORT%20Spring%202015.pdf?dl=0), which is an environmental and energy efficiency program designed to reduce household heating and cooling energy use by increasing tree canopy cover in urban residential areas in the state's Gateway Cities (http://www.mass.gov/hed/community/planning/gateway-cities-and-program-information.html). GGCP is a partnership between EEA, the Department of Conservation and Recreation (DCR), the Department of Energy Resources (DOER), and the Department of Housing and Community Development (DHCD), along with Gateway Cities and local grassroots organizations. The program plants new trees, with a goal of covering 10% of the target neighborhoods in new tree canopy cover to achieve reductions in energy needs for cooling and heating resulting from the increased tree canopy, which lowers wind speeds, provides shade, and reduces summertime air temperature. The GGCP is a unique way to reduce energy costs for LMI residents and has developed a fine-tuned process where tenants request trees and agree to provide watering for two years and get sign-off from landlords for plantings.

The Trees for Resilience Program proposed by the Commonwealth in this Phase 2 application will expand and enhance the GCCP by securing additional funds to target and prioritize tree plantings in LMI neighborhoods in Massachusetts communities, specifically Greenfield and Springfield (Figures E-1 and E-2), and also incorporate installation of tree box filters (which are not in the scope of the GCCP) to achieve additional stormwater benefits. This program has been closely coordinated with the City of Springfield, also an NDRC applicant. The City is requesting approximately 7,000 trees and 25 stormwater tree box filters. The MA Team intends to plant a similar number using both HUD and leverage funds. Execution of this program in Springfield will be a single united effort with the City. The MA Team and the City have evaluated Springfield's EJ neighborhoods with highest loss to select the area of tree installation (Figure E-2). The key objectives of this program include:

- Replacing trees that were destroyed by natural disasters
- Making urban neighborhoods more resilient to future disasters by increasing tree canopy and the presence of green infrastructure

- Reducing energy costs for LMI populations
- Training local residents and creating urban forestry jobs

The Trees for Resilience Program consists of two main activities: 1) greening urban LMI neighborhoods through the planting of trees in public rights-of-way and on other public properties, and 2) the installation of tree box filters. The tree planting in Greenfield and Springfield will be carried out by two 11-person crews (each crew includes two foresters who supervise the crew and conduct outreach meetings with the community, city officials, neighborhood associations, and residents). Approximately 3,220 public trees will be planted by the two crews within a two year period using the requested HUD funds, and approximately 4,830 private trees will be planted in the following three years using other funds secured by the state. ReGreen Springfield will help with local outreach and train tree planting crew members so that they become Massachusetts Certified Landscape Professionals while they are in the program, which will help with future arboriculture and landscaping employment.

The tree box filter activity includes planting of additional trees with tree box filters in key public locations to address stormwater runoff in Greenfield and Springfield and aid in reducing combined sewer overflows in Springfield. A total of 37 tree box filters are proposed: 12 in Greenfield and 25 in Springfield. The tree box filters will be installed concurrent with the two years of public tree planting. As part of this activity, UMass Amherst will establish a water quality monitoring program for the tree filters and control sites within the City of Springfield.

The estimated useful life of the project is 50 years. The base-case discount rate in Office of Management and Budget (OMB) Circular A-94 (7%) was used for the BCA analysis. An alternative discount rate of 3% was also used for comparison following guidance from HUD and OMB.

5. Risk if Proposal is Not Implemented

If the Trees for Resilience Program is not implemented, the cities of Greenfield and Springfield will not have a strengthened natural line of defense against future tornado and flood disasters. Without the proposed tree plantings, wind speeds will continue to be higher for the affected LMI areas. Measurement of wind speed (a good proxy for heating energy demand by older, poorly-insulated houses) in Springfield following destruction of trees as a result of the 2011 tornadoes, indicated a 66% increase in wind speed compared to baseline conditions when the trees existed (Morzuch 2013). Stormwater runoff will be greater during storm events since there will be less vegetation. Trees promote evapotranspiration and interception (trees hold hundreds of gallons of water in their canopy that evaporates instead of landing on pavement and lawns and becoming stormwater) of stormwater that would otherwise run off into local streams, and each tree box filter installation is the equivalent of removing 1,000 square feet of pavement in terms of stormwater flow and treatment reductions (USEPA 2015). Climate change is expected to result in increases in the frequency and intensity of storm events for Massachusetts, so the current risks are only expected to be greater in the future. Furthermore, energy savings to LMI residents and new urban forestry jobs that are anticipated as a result of implementation of this project would not be realized, resulting in lost opportunity economic benefits from cost savings to vulnerable populations and job creation.

6. Categories of Costs and Benefits

6.1. Benefit-Cost Analysis Overview

The economic analysis estimates the impact to Greenfield and Springfield from planting trees on both residential and commercial property. The project assumes the impact to the region from trees planted using both public funds and private funds. Public funds will support the planting of trees during the first two years of the program, while private funds will support the planting of trees during the third, fourth, and fifth years of the program[1]. The project assumes that 3,200 and 4,830 publically-funded and privately-funded trees will be planted, respectively (Table 3).

Underpinning the analysis is the assumption that 90 percent of the trees will be planted on residential property while the residual will be planted on commercial property[2]. In addition, 12 and 25 tree box filters will be installed in Greenfield and Springfield, respectively (Table 4). This will occur over the first two years of the analysis under the assumption that an equal share will be planted among those two years.

Table 3. Quantity and Location of Trees

Community	No. of Public Trees (40% of trees - HUD)	No. of Private Trees (60% of trees - EEA)	Total No. of Trees
Greenfield	386	579	965
Springfield	2,834	4,251	7,085
TOTAL	3,220	4,830	8,050

Source: Values were provided to AECOM from Robert O'Connor, Director of Land and Forest Conservation, EEA, October 8, 2015.

[1] The analysis assumes that the share of publically-funded trees that are planted will be equally distributed across the first two years of the program while the share of privately-funded trees that are planted will be equally distributed across the third, fourth and fifth years of the program.
[2] Single-family homes represent impacts to residential properties and small, commercial businesses represent impacts to commercial properties when using estimated impacts from treebenefits.com.

Table 4. Proposed Tree Box Filters

Community	Number of Tree Box Filters
Springfield	25
Greenfield	12
TOTAL	37

Source: Values were provided to AECOM from Robert O'Connor, Director of Land and Forest Conservation, EEA, October 8, 2015.

Five types of genus will be planted (Table 5). The analysis assumes that the distribution of type of genus is the same for Greenfield and Springfield for individual trees planted without tree boxes. Conversely, 100 percent of the trees planted within tree boxes will be of the Cornus genus.

Table 5. Proposed Types of Trees and Growth Rates

Genus (Specific Tree)	Number of Trees	Growth per year		Distribution
Acer (Silver Maple)[3]	309	0.49	inch	27.9%
Quercus (White Oak)[4]	266	0.43	inch	24.0%
Carpinus (American Hornbeam)	214	0.23	inch	19.3%
Prunus (Plum Cherry)	163	0.67	inch	14.7%
Cornus (Dogwood)	156	0.34	inch	14.1%

Source: AECOM analysis

Based on previous programs and sample sizes from the State of Massachusetts, the survival rate of trees is roughly 80 percent. Of the 20 percent that fail, 10 percent are assumed to

[3] Wood, Keith, *Growth Rates of Common Tree Species in Westminster, Colorado*, Colorado State Forest Service, January, 2010, http://static.colostate.edu/client-files/csfs/pdfs/FINAL_Tree_Growth_Rate_Study.pdf
[4] Ibid.

fail during the first year, and 10 percent are assumed to fail during the second year of being planted. After the second year, the analysis assumes the tree will survive. Furthermore, the analysis assumes that 100 percent of trees planted within tree boxes will survive.

Based on the diameter at breast height (DBH) of the tree at planting (one inch) and the rate of growth of each genus of tree per year, the analysis estimates the stormwater, electricity, air quality, property value, natural gas, and CO_2 benefits for each incremental increase in diameter per year over a 50 year analysis period (49 years of benefits for the trees that are planted in the second year of the program and so on)[5].

6.2. Costs

The costs incurred over the analysis period are the capital costs of purchasing and planting trees and tree box filters and the operating and maintenance cost of watering the trees for the first two years after planting. Pruning costs are negligible. Additional costs include $265,000[6] for the first two years for ReGreen Springfield to conduct outreach and educational efforts that will work within Springfield neighborhoods to locate appropriate tree locations, coordinate tree watering agreements and train tree planting crews; and $50,000[7] over the first five years for UMass Amherst to establish a water quality monitoring program for the tree filters and control sites within the City of Springfield. The cost per tree for those not planted in a tree box is identified in Table 6.

The cost of installing a tree box filter is $11,786, and this includes the cost of the tree for the tree box[8]. The useful life of a tree box is assumed to be 50 years[9], meaning the cost of

[5] Treebenefits.com/calculator, accessed October 8, 2015.
[6] This cost is equally incurred over the first two years of the analysis period. This means that a per annum cost of $132,500 is incurred in years one and two.
[7] This cost is equally incurred over the first five years of the analysis period. This means that a per annum cost of $10,000 is incurred in years one through five.
[8] U,S, Environmental Protection Agency, *Birch Street Drainage Area Green Infrastructure Pilot Program*, 2015.
[9] Water Environment Research Foundation, *User's Guide to the BMP and LID Whole Life Cost Models*, 2009.

installing tree boxes will be incurred only in years one and two of the analysis period. Half way through the lifecycle of a tree box, a new tree and replacement media is installed, costing $1,309 per tree box[10]. A $2.89 cost to water each tree for the first two years the tree is planted is included in the analysis. This equals a $1.45 cost per tree per year over a two year period. This cost would be included each time a new tree is planted within a tree box[11].

Table 6. Average Tree Cost

Cost of planting a tree (no tree box)	Public Cost per tree	Private Cost per tree
Greenfield	$950	$575
Springfield	$575	$575

Source: Values were provided to AECOM from Robert O'Connor, Director of Land and Forest Conservation, EEA, October 8, 2015.

All costs are estimated in 2015 dollars and are discounted to 2015 over a 50 year period. The analysis discounts the annual costs at a rate of seven and three percent because both public and private funds will be used to finance the program.

The discounted stream of costs for the total program equal $4.63 million (2015$) and $5.14 million (2015$) discounted seven and three percent, respectively.

[10] U,S, Environmental Protection Agency, *Birch Street Drainage Area Green Infrastructure Pilot Program*, 2015.

[11] Residents will be required to water trees for the first two years that they are installed. The derivation of the cost is as follows: 15 gallons/week X 26 weeks/year X 2 years = 780 gallons per tree (times the Springfield cost for retail water = $.037/gallon) = $2.89 per tree for 2 year. This cost is used for both publically-funded and privately-funded trees in both Greenfield and Springfield to remain conservative. This cost was provided to AECOM from Robert O'Connor, EEA, Director of Land and Forest Conservation, October 7, 2015.

Table 7.Total Project Costs for 50-Year Analysis

	7% Discount Rate (2015$ M)	3% Discount Rate (2015$ M)
Project Costs	$4.63	$5.14

Source: AECOM analysis

6.3. Benefits

The BCA analysis estimates four types of benefits: resiliency value, environmental value, community development value, and economic revitalization.

The benefits are based on the genus and DBH of the tree. A larger DBH will yield higher benefits[12]. Thus, the benefits are a function of the rate of growth of each genus. The model assumes trees are planted in 2016 and residents will immediately realize benefits. However, the benefits realized in 2016 will be less than the benefits realized in later years due to the smaller size of the tree in 2016.

All benefits are estimated in 2015 dollars and are discounted to 2015 over a 50 year period. The analysis discounts the annual benefits at a rate of seven and three percent because both public and private funds will be used to finance the program.

Resiliency Value

Resiliency benefits for Greenfield and Springfield are the benefits of stormwater reduction from trees themselves. Furthermore, the tree box filters result in an additional benefit from a reduction in stormwater flooding. Each tree box will divert 25,000 gallons of water annually[13]. Storm runoff washes chemicals from surfaces into water sources such as streams and

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[12] The benefits for each type of genus based on the DBH and the type of property the tree is planted on is determined using treebenefits.com

[13] The cost to treat 1 gallon of water in the Calument region is $0.000093 (2015 $) and is used as a proxy for the treatment cost in Greenfield and Springfield based on the availability of data. If costs were higher in Greenfield and Springfield, the benefits per tree box would increase. Conversely, if the costs were lower in Greenfield and Springfield, the benefits per tree box would decrease. Alon, L. et. al. 2014. *A Summary of Environmental Quality*

rivers, and thus increases the rate at which pollutants are washed into community waterways. As a result, drinking water, aquatic life, and community health are negatively impacted. Trees can help mitigate these negative impacts by intercepting and holding rain; increasing infiltration and storage of rainwater through the root system; and reducing soil erosion[14].

Based on the mix of trees planted and DBH[15], the stormwater cost avoided per tree planted without a tree box ranges from $0.32 in year one to $18.70 in year 50. The stormwater cost avoided per tree planted with a tree box ranges from $0.27 in year one to $3.58 in year 50[16].

The discounted stream of benefits equals $0.33 million (2015$) and $0.97 million (2015$) discounted seven and three percent, respectively (Table 8).

Table 8. Resiliency Value

	7% Discount Rate (2015$ M)	**3% Discount Rate (2015$ M)**
Stormwater Costs Avoided	$0.33	$0.97

Source: AECOM analysis

and Stormwater Management and Green Infrastructure in the Calumet Region. Available: http://calumetquarter.uchicago.edu/2014/a-summary-of-environmental-quality-and-stormwater-management-and-green-infrastructure-in-the-calumet-region

[14] National Tree Benefit Calculator, treebenefits.com. Accessed 10.21.15.

[15] The benefits realized increase as the DBH increases. Thus, the range provided shows the lowest benefits realized based on the DBH at the time of planting (1 inch) to the DBH in the last year of analysis. Only trees planted without boxes in year 1 that survive a full 50 years will reach the maximum benefit. Those trees planted in subsequent periods or in tree boxes will realize fewer benefits in the last year of analysis because these trees are younger, and thus, their DBH is smaller.

[16] The values between benefits for trees planted with and without tree boxes differ because only trees of the cornus genus are installed within tree boxes. This holds true for all benefits realized.

Environmental Value

Environmental benefits are the aggregated benefits from a reduction in carbon dioxide and other pollutants. Trees absorb pollutants; intercept particulate matter; release oxygen; lower air temperatures; and reduce energy use and subsequent emissions from power plants.

Based on the mix of trees planted and DBH, the CO_2 cost avoided per tree planted without a tree box ranges from $0.03 in year one to $2.13 in year 50. The CO_2 cost avoided per tree planted with a tree box ranges from $0.04 in year one to $0.60 in year 50. Based on the mix of trees planted and DBH, the improvement to air quality benefit per tree planted without a tree box ranges from $0.46 in year one to $13.86 in year 50. The improvement to air quality benefit per tree planted with a tree box ranges from $0.31 in year one to $4.12 in year 50.

The discounted stream of benefits for a reduction in carbon dioxide equals $37,600 (2015$) and $111,700 (2015$) discounted seven and thee percent, respectively. The discounted stream of benefits for air quality improvements equals $277,600 (2015$) and $792,100 (2015$) discounted seven and three percent, respectively (Table 9).

Table 9. Environmental Value

	7% Discount Rate (2015$ M)	**3% Discount Rate (2015$ M)**
CO_2 Costs Avoided	$0.28	$0.79
Air Quality Improvements Benefits	$0.00	$0.00
Total	$0.28	$0.80

Source: AECOM analysis

Community Development Value

The community development benefits realized by the local community are the reduction in electricity and natural gas costs due a reducing in energy consumption. Trees modify climate and conserve building energy use. Shade reduces the amount of heat absorbed by buildings; evapotranspiration converts liquid water to water vapor and cools the air by using solar energy that would otherwise result in heating of the air; and tree canopies slow down winds and thus reduce the amount of heat lost from a home[17].

Based on the mix of trees planted and DBH, the electricity cost avoided benefit per tree planted without a tree box ranges from $0.36 in year one to $15.33 in year 50. The electricity cost avoided benefit per tree planted with a tree box ranges from $0.34 in year one to $4.55 in year 50. Based on the mix of trees planted and DBH, the natural gas cost avoided benefit per tree planted without a tree box ranges from $1.85 in year one to $58.31 in year 50. The natural gas cost avoided benefit per tree planted with a tree box ranges from $1.96 in year one to $22.09 in year 50.

The discounted stream of benefits for electricity costs avoided equals $0.32 million (2015$) and $0.91 million (2015$) discounted seven and three percent, respectively (Table 10). The discounted stream of benefits for natural gas costs avoided equals $1.32 million (2015$) and $3.67 million (2015$) discounted seven and three percent, respectively (Table 10).

Table 10. Community Development Value

	7% Discount Rate (2015$ M)	**3% Discount Rate (2015$ M)**
Electricity Costs Avoided	$0.32	$0.91
Natural Gas Costs Avoided	$1.32	$3.67
Total	$1.64	$4.58

Source: AECOM analysis

[17] National Tree Benefit Calculator, treebenefits.com. Accessed 10.21.15.

Economic Revitalization

The economic benefits for Greenfield and Springfield from the program will be the increase in property value to a home or business. An increase in a tree's leaf surface area increases the property value by boosting the appeal of a home, and thus, increasing the sale price. Additionally, a tree located on a commercial property will increase the property value; however, to a lesser degree than for residential properties.

Based on the mix of trees planted and DBH, the increase to property value benefit per tree planted on residential property without a tree box ranges from $20.86 in year one to $52.62 in year 50. The increase to property value benefit per tree planted on residential property with a tree box ranges from $5.77 in year one to $14.00 in year 50. Based on the mix of trees planted and DBH, the increase to property value benefit per tree planted on commercial property without a tree box ranges from $18.01 in year one to $34.73 in year 50. The increase to property value benefit per tree planted on commercial property with a tree box ranges from $3.81 in year one to $9.24 in year 50.

The discounted stream of benefits for the total program equals $2.63 million (2015$) and $5.70 million (2015$) discounted seven and three percent, respectively (Table 11).

Table 11. Economic Revitalization

	7% Discount Rate (2015$ M)	**3% Discount Rate (2015$ M)**
Property Value Benefits	$2.63	$5.69

Source: AECOM analysis

6.2 Benefit-Cost Analysis Conclusion

The program will yield a positive net present value discounted seven and three percent over the 50-year analysis period. The program yields a benefit cost ratio of 1.1 and 2.4 when discounted seven and three percent, respectively. The results are shown in Table 12.

Table 12. Net Present Value and Benefit-Cost Ratio Results

	7% Discount Rate (2015 $ M)	**3% Discount Rate (2015 $ M)**
Benefits	$4.91	$12.15
Costs	$4.63	$5.14
Net Present Value	$0.28	$7.01
Benefit Cost Ratio	1.1	2.4

Source: AECOM analysis

The following matrix (Table 13) provides a description of the dollar value used to estimate program costs and benefits. The matrix provides the cost or benefit category, the page number in which these costs are described and factored into the analysis, a brief description of the reasoning for including this value in the analysis, a description of the methodology for deriving this value, the dollar value, and a level of uncertainty of the value in determining the results. This is a range between 1-5, with 1 representing “very certain” and 5 representing “very uncertain”. Also, Table 14 provides a summary of lifecycle costs and benefits for the project.

Table 13. Costs and Benefits by Category

1	2	3	4	5	6
Costs and Benefits by category	**Page # in Factor Narratives or BCA Attachment**	**Qualitative Description of Effect and Rationale for Including in BCA**	**Quantitative assessment (Explain basis and/or methodology for calculating Monetized Effect, including data sources, if applicable)**	**Monetized effect (if applicable)**	**Uncertainty**
Life cycle costs					
Public Cost to plant a tree in Springfield	AttF-12	This is a one-time cost for each tree planted	Monetized impact is based on project team analysis	$575	1
Public Cost to plant a tree in Greenfield	AttF-12	This is a one-time cost for each tree planted	Monetized impact is based on project team analysis	$950	1
Private Cost to plant a tree in Springfield	AttF-12	This is a one-time cost for each tree planted	Monetized impact is based on project team analysis	$575	1
Private Cost to plant a tree in Greenfield	AttF-12	This is a one-time cost for each tree planted	Monetized impact is based on project team analysis	$575	1
Cost to install a tree box	AttF-11	This is a one-time cost for each tree box installed	Monetized impact is based on tree box filter cost detail provided in EPA's *Birch Street Drainage Area Green Infrastructure Pilot Program*, 2015 publication.	$11,786	1
Media Cost	AttF-12	This is a one-time cost for each tree	Monetized impact is based on tree box filter	$1,309	1

		box installed incurred roughly half-way through the lifecycle of a tree box.	cost detail provided in EPA's *Birch Street Drainage Area Green Infrastructure Pilot Program*, 2015 publication.		
Annual Watering Cost	AttF-12	This cost is incurred for the first two years that the tree is planted on a residential or commercial property. Applied to both trees with and without tree boxes.	Monetized impact is based on project team analysis	$1.45/year	1
UMass Cost	AttF-11	This cost in incurred over the first five years of the analysis to establish a water quality monitoring program for the tree filters and control sites within the City of Springfield.	Monetized impact is based on direction from the State of Massachusetts	$10,000/year	1
ReGreen Springfield	AttF-11	This cost in incurred over the first two years of the analysis to conduct outreach and educational efforts that will work within Springfield neighborhoods to locate appropriate	Monetized impact is based on direction from the State of Massachusetts	$132,500/year	1

		tree locations, coordinate tree watering agreements and train tree planting crews.			
Resiliency Value					
Storm Water Benefits for trees without tree boxes	AttF-14	Range of value of benefits per tree planted. This is based on the mix of trees planted and the benefits per tree genus.	Based on estimates from treebenefits.com	\$0.32 in year one to \$18.70 in year 50	2
Storm Water Benefits for trees with tree boxes	AttF-14	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	\$0.27 in year one to \$3.58 in year 50	2
Water Treatment Cost Avoided	AttF-13	Dollar per gallon treatment cost for the Calumet Region. This cost is used a proxy for Greenfield and Springfield due to the lack of data available for the assessment area.	2014 value is inflated to 2015 dollars. Source: Alon, L. et. al. 2014. A Summary of Environmental Quality and Stormwater Management and Green Infrastructure in the Calumet Region	\$0.000093	3
Environmental Value					
CO_2 Benefits for trees without tree boxes	AttF-15	Range of value of benefits per tree planted. This is based on the mix of	Based on estimates from treebenefits.com	\$0.03 in year one to \$2.13 in year 50	2

		trees planted and the benefits per tree genus.			
CO_2 Benefits for trees with tree boxes	AttF-15	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	\$0.04 in year one to \$0.60 in year 50	2
Air Quality Benefits for trees without tree boxes	AttF-15	Range of value of benefits per tree planted. This is based on the mix of trees planted and the benefits per tree genus.	Based on estimates from treebenefits.com	\$0.46 in year one to \$13.86 in year 50	2
Air Quality Benefits for trees with tree boxes	AttF-15	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	\$0.31 in year one to \$4.12 in year 50	2
Community Development Value					
Electricity Benefits for trees without tree boxes	AttF-16	Range of value of benefits per tree planted. This is based on the mix of trees planted and the benefits per tree genus.	Based on estimates from treebenefits.com	\$0.36 in year one to \$15.33 in year 50	2
Electricity Benefits for trees with tree boxes	AttF-16	Range of value of benefits per tree planted. This is	Based on estimates from treebenefits.com	\$0.34 in year one to \$4.55 in year 50	2

		based the benefits from the Cornus genus.			
Natural Gas Benefits for trees without tree boxes	AttF-16	Range of value of benefits per tree planted. This is based on the mix of trees planted and the benefits per tree genus.	Based on estimates from treebenefits.com	$1.85 in year one to $58.31 in year 50	2
Natural Gas Benefits for trees with tree boxes	AttF-16	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	$1.96 in year one to $22.09 in year 50	2
Economic Revitalization					
Property Value Benefits for trees planted on residential property without tree boxes	AttF-17	Range of value of benefits per tree planted. This is based on the mix of trees planted and the benefits per tree genus.	Based on estimates from treebenefits.com	$20.86 in year one to $56.62 in year 50	2
Property Value Benefits for trees planted on residential property with tree boxes	AttF-17	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	$5.77 in year one to $14.00 in year 50	2
Property Value Benefits for trees planted on commercial property	AttF-17	Range of value of benefits per tree planted. This is	Based on estimates from treebenefits.com	$18.01 in year one to $34.73 in year 50	2

without tree boxes		based on the mix of trees planted and the benefits per tree genus.			
Property Value Benefits for trees planted on commercial property with tree boxes	AttF-17	Range of value of benefits per tree planted. This is based the benefits from the Cornus genus.	Based on estimates from treebenefits.com	$3.81 in year one to $9.24 in year 50	2

Table 14. Lifecycle Costs and Benefits Summary

Calendar Year	Period	Lifecycle Costs	Discounted Costs		Resiliency Benefit	Environmental Benefit	Social Benefit	Economic Revitalization	Total Project Benefits	Discounted Benefits		Discounted Net Benefits	
			7%	3%						7%	3%	7%	3%
2016	0	$1,361,151	$1,272,104	$1,321,506	$514	$690	$3,242	$29,892	$34,337	$32,090	$33,337	($1,240,013)	($1,288,169)
2017	1	$1,363,403	$1,190,849	$1,285,138	$1,322	$1,611	$7,991	$59,117	$70,041	$61,177	$66,021	($1,129,672)	($1,219,117)
2018	2	$940,460	$767,696	$860,654	$2,432	$2,835	$14,565	$90,806	$110,638	$90,314	$101,250	($677,382)	($759,405)
2019	3	$940,433	$717,452	$835,563	$3,892	$4,369	$22,988	$124,975	$156,223	$119,182	$138,802	($598,270)	($696,761)
2020	4	$940,433	$670,516	$811,226	$5,703	$6,214	$33,265	$161,565	$206,747	$147,408	$178,342	($523,108)	($632,884)
2021	5	$2,225	$1,483	$1,864	$7,404	$7,690	$42,203	$170,732	$228,028	$151,945	$190,970	$150,462	$189,106
2022	6	$0	$0	$0	$9,128	$9,219	$51,467	$183,919	$253,733	$158,012	$206,308	$158,012	$206,308
2023	7	$0	$0	$0	$10,919	$10,824	$60,939	$195,170	$277,853	$161,713	$219,339	$161,713	$219,339
2024	8	$0	$0	$0	$12,776	$12,505	$70,625	$204,550	$300,456	$163,428	$230,275	$163,428	$230,275
2025	9	$0	$0	$0	$14,697	$14,262	$80,528	$212,125	$321,612	$163,491	$239,310	$163,491	$239,310
2026	10	$0	$0	$0	$16,684	$16,095	$90,657	$217,941	$341,376	$162,185	$246,617	$162,185	$246,617
2027	11	$0	$0	$0	$18,777	$18,040	$101,069	$221,024	$358,910	$159,360	$251,732	$159,360	$251,732
2028	12	$0	$0	$0	$20,848	$19,957	$111,384	$224,132	$376,321	$156,160	$256,256	$156,160	$256,256
2029	13	$0	$0	$0	$22,941	$21,903	$121,681	$227,210	$393,735	$152,697	$260,305	$152,697	$260,305
2030	14	$0	$0	$0	$25,059	$23,882	$131,978	$230,261	$411,180	$149,031	$263,921	$149,031	$263,921
2031	15	$0	$0	$0	$27,204	$25,900	$142,286	$233,287	$428,677	$145,208	$267,137	$145,208	$267,137
2032	16	$0	$0	$0	$29,377	$27,958	$152,614	$236,289	$446,238	$141,267	$269,981	$141,267	$269,981
2033	17	$0	$0	$0	$31,615	$30,100	$163,119	$239,236	$464,069	$137,301	$272,592	$137,301	$272,592
2034	18	$0	$0	$0	$33,803	$32,172	$173,380	$242,184	$481,539	$133,150	$274,615	$133,150	$274,615
2035	19	$0	$0	$0	$36,038	$34,294	$183,713	$245,098	$499,144	$128,988	$276,364	$128,988	$276,364
2036	20	$0	$0	$0	$38,317	$36,461	$194,099	$247,980	$516,857	$124,828	$277,836	$124,828	$277,836
2037	21	$0	$0	$0	$40,636	$38,669	$204,520	$250,829	$534,653	$120,678	$279,032	$120,678	$279,032
2038	22	$0	$0	$0	$42,993	$40,912	$214,960	$253,647	$552,511	$116,550	$279,953	$116,550	$279,953
2039	23	$0	$0	$0	$45,460	$43,286	$225,750	$256,433	$570,930	$112,557	$280,860	$112,557	$280,860
2040	24	$0	$0	$0	$47,893	$45,624	$236,357	$259,134	$589,007	$108,524	$281,313	$108,524	$281,313
2041	25	$24,243	$4,175	$11,241	$50,310	$47,913	$246,653	$261,794	$606,670	$104,466	$281,310	$100,291	$270,068

Calendar Year	Period	Lifecycle Costs	Discounted Costs		Resiliency Benefit	Environmental Benefit	Social Benefit	Economic Revitalization	Total Project Benefits	Discounted Benefits		Discounted Net Benefits	
			7%	3%						7%	3%	7%	3%
2042	26	$24,270	$3,906	$10,926	$52,714	$50,155	$256,637	$264,396	$623,902	$100,405	$280,874	$96,499	$269,948
2043	27	$27	$4	$12	$55,187	$52,453	$266,903	$267,124	$641,666	$96,508	$280,457	$96,504	$280,446
2044	28	$0	$0	$0	$57,670	$54,724	$276,988	$269,834	$659,216	$92,661	$279,736	$92,661	$279,736
2045	29	$0	$0	$0	$60,184	$56,982	$286,924	$272,544	$676,634	$88,887	$278,764	$88,887	$278,764
2046	30	$0	$0	$0	$62,665	$59,258	$296,940	$275,233	$694,096	$85,216	$277,630	$85,216	$277,630
2047	31	$0	$0	$0	$65,178	$61,490	$306,696	$277,908	$711,272	$81,612	$276,213	$81,612	$276,213
2048	32	$0	$0	$0	$67,720	$63,681	$316,200	$280,562	$728,163	$78,084	$274,537	$78,084	$274,537
2049	33	$0	$0	$0	$70,288	$65,833	$325,459	$283,191	$744,771	$74,640	$272,619	$74,640	$272,619
2050	34	$0	$0	$0	$72,879	$67,945	$334,478	$285,801	$761,103	$71,287	$270,483	$71,287	$270,483
2051	35	$0	$0	$0	$75,538	$69,993	$343,148	$288,420	$777,100	$68,024	$268,125	$68,024	$268,125
2052	36	$0	$0	$0	$78,197	$72,042	$351,819	$291,039	$793,097	$64,882	$265,674	$64,882	$265,674
2053	37	$0	$0	$0	$80,892	$74,098	$360,466	$293,657	$809,113	$61,862	$263,145	$61,862	$263,145
2054	38	$0	$0	$0	$83,623	$76,161	$369,090	$296,273	$825,146	$58,961	$260,543	$58,961	$260,543
2055	39	$0	$0	$0	$86,389	$78,230	$377,689	$298,888	$841,197	$56,175	$257,875	$56,175	$257,875
2056	40	$0	$0	$0	$89,191	$80,308	$386,266	$301,502	$857,266	$53,503	$255,146	$53,503	$255,146
2057	41	$0	$0	$0	$92,029	$82,392	$394,819	$304,115	$873,354	$50,942	$252,364	$50,942	$252,364
2058	42	$0	$0	$0	$94,866	$84,476	$403,373	$306,727	$889,443	$48,486	$249,527	$48,486	$249,527
2059	43	$0	$0	$0	$97,703	$86,550	$411,766	$309,272	$905,290	$46,121	$246,576	$46,121	$246,576
2060	44	$0	$0	$0	$100,538	$88,612	$420,000	$311,747	$920,897	$43,847	$243,521	$43,847	$243,521
2061	45	$0	$0	$0	$103,372	$90,663	$428,074	$314,154	$936,263	$41,662	$240,373	$41,662	$240,373
2062	46	$0	$0	$0	$106,205	$92,703	$435,988	$316,493	$951,389	$39,566	$237,142	$39,566	$237,142
2063	47	$0	$0	$0	$109,038	$94,732	$443,742	$318,763	$966,274	$37,556	$233,837	$37,556	$233,837
2064	48	$0	$0	$0	$111,870	$96,760	$451,496	$321,033	$981,159	$35,640	$230,524	$35,640	$230,524
2065	49	$0	$0	$0	$114,753	$98,844	$459,312	$323,289	$996,198	$33,819	$227,240	$33,819	$227,240
TOTAL		**$5,596,646**	**$4,628,183**	**$5,138,130**	**$2,585,431**	**$2,372,467**	**$11,786,307**	**$12,351,291**	**$29,095,497**	**$4,912,059**	**$12,146,701**	**$283,876**	**$7,008,571**

6.3 Qualitative Benefits Discussion

Increased tree density in urban communities can have several positive environmental effects. Through their natural metabolizing processes, trees reduce the effects of harmful automobile and industrial exhaust fumes, which can be a major public health concern in urban environments. Carbon monoxide, sulphur dioxide, nitrogen oxide, and particulate matter are all toxic components of automobile emissions. These toxins are associated with fatal health conditions including stroke, lung disease, heart cancer, asthma, and respiratory infections. According to the World Health Organization (WHO), air pollution caused 3.7 million premature deaths globally in 2012 (WHO 2015). Trees significantly reduce toxic compounds in the atmosphere by absorbing large quantities of the pollutants and filtering out these toxins from the air. The *Journal of Epidemiology and Community Health* reported that childhood asthma rates decreased by 25% for every 340 trees per square kilometer (Lovasi 2008). According to the Center for Urban Forest Research, the tree canopy of Houston, TX removes an estimated 60,575 tons of air pollutants annually, which is valued at $300 million in associated health costs (McPherson 2006). Additionally, urban trees in Los Angeles, CA annually remove about 77,000 tons of carbon from the atmosphere and about 1,976 tons of air pollution (Nowak 2011).

An increase in trees can also improve stormwater absorption and decrease the need for drainage infrastructure. Trees absorb the initial 30% of liquid precipitation through their leaf systems and up to an additional 30% through their root systems (Burden 2006). A mature tree can store from 50 to 100 gallons of water during larger storms. The remaining precipitation seeps into the groundwater or becomes stormwater runoff, which can cause significant flooding damage to urban infrastructure as well as soil environments. Runoff can deplete soils of essential nutrients and cause erosion of soiled foundations. Trees reduce the need for drainage infrastructure and degradation of soil environments by reducing annual stormwater runoff by 2-7%. (Fazio 2010) Stormwater runoff can also have negative effects on sewage volumes and cause sewer overflow. In the sewage and water department of Detroit, incorporating trees and green infrastructure practices reduced overflow volumes by 10-20% and reduced annual costs by $159 million a year (Berkooz 2011).

In urban environments, trees provide protection from the elements to both people and paved surfaces. Between tree shaded and non-shaded areas, there can be a 5-15 degree difference in temperature. Paved surfaces can increase urban temperatures up to 7 degrees, leading to higher energy costs for both residential and commercial properties. (Burden 2006) Trees aligning residential or commercial streets can reduce energy bills up from 15-35%. Additionally, trees can prolong the life of pavement by up to 60%. The daily heating and cooling of these surfaces, combined with the seasonal changes, causes expansions and contractions of the pavement. Over time, this movement creates major cracks and fissures in the asphalt, which are safety hazards to both pedestrians and motorists that need regular maintenance. Trees reduce the surface's exposure to the elements and thus reduce maintenance costs of paved spaces.

Increased tree density in urban communities can also improve mental health of residents. The *Journal of Attention Disorders* examined the effects of environments on children with ADHD, comparing time spent in treed spaces against non-treed downtown and residential areas. Results determined that 20 minutes in a natural park setting improved the concentration and focus of the children to the same degree that ADHD medication affected children in the urban and residential settings, concluding that time spent in a natural setting could be used as a safer and less expensive alternative to medication (Taylor 2008). Increasing tree density and incorporating more natural elements into urban areas could help residents who struggle with attention and focus.

Improved mental functioning associated with greater tree density also applies to the work force. The University of Michigan examined the impacts of greener environments on worker productivity and determined that employees without views of nature and trees from their desk claimed 23% more sick days than those with views of nature and trees.

Finally, trees create safer spaces for both pedestrians and motorists and have aesthetical benefits in urban areas. Tree-lined streets create more focused driving environments for motorists and safer walking areas for pedestrians. Correctly situated, trees effectively create a vertical framing that provides drivers with a well-defined boundary within which to focus, reducing accident-causing distractions. Additionally, trees aligning streets provide motorists with a method to gauge their speed. By comparing their speed against stationary trees, motorists are more aware of their speed and have a tendency to drive slower along a treed street.

The framing created by the trees for the motorists also provides protection to pedestrians walking along sidewalks. The trees provide a clearly distinguished barrier between the pedestrian's and motorist's space. This enables both to better differentiate between the two areas and remain within their boundaries. If a motorist accidentally crosses into the pedestrian's space, trees provide a physical barrier protecting pedestrians from fatal impacts by vehicles.

Aesthetically, trees in urban areas camouflage what some would consider unsightly features of urban environments including light poles, utility poles, parked cars, and other structures necessary for urban safety and function. Also, trees create green backdrops that allow for other features of an urban environment to be seen. Properly positioned storefront signs become more dominant and more effectively draw consumer's attention, leading to increased retail sales. Business with treed storefronts can record a 12% income increase over non-treed storefronts.

7. Risks to Ongoing Benefits

One risk to the Trees for Resilience Program includes the occurrence of another natural disaster that could destroy some of the trees planted through this project. However, the overall objective of the project is to promote resilience by mitigating effects from future disasters by decreasing wind speeds, resulting in stormwater quantity and quality benefits, and moderating extreme temperatures. While some trees may be lost due to a future disaster, it is expected that the vast majority of planted trees will survive and still achieve the intent of the program.

Another risk to the survival rate of the trees planted under this program is extended drought conditions while the trees are becoming established. However, the project includes an intensive public outreach element that informs residents, business owners, and municipalities about the importance of watering and other needs, and watering agreements are executed with tree recipients to minimize the rate of tree mortality due to poor conditions.

8. Challenges with Implementation

One possible challenge with implementation of the Trees for Resilience Program is lack of interest or willingness from local residents and/or landlords for installation of tress. In order to increase awareness of the program and buy in, the project includes a strong public outreach component that will utilize bi-lingual (English and Spanish) public relations materials and an implementation template previously developed for the GGCP. Also, the tree planting crews will be working in neighborhoods in Greenfield and Springfield for five years (two years for the public trees and three years for the private trees), with daily contact with residents and property owners. Tree planting crews are hired from the community and adjacent areas, providing employment as well as furthering community connections. They will be working with respected community groups, and will have capacity through staffing and training to assist with potential language and cultural barriers.

The Trees for Resilience Program also includes a partnership with the local non-profit ReGreen Springfield, which has already worked with EEA and the City of Springfield to plant 1,100 trees in tornado affected neighborhoods via a federal Department of Energy grant in 2012. ReGreen completed outreach and worked with the community to fund an additional 400 trees with local funding in this project. ReGreen will help with local outreach and train crew members so that they become Massachusetts Certified

Landscape Professionals while they are in the program, which will help with future arboriculture and landscaping employment in these communities.

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